The Quality of Tortillas Containing Whole Sorghum and Pearled Sorghum Alone and Blended with Yellow Maize

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ABSTRACT

Tortillas were prepared by replacing 0, 25, 50, 75, and 100% of yellow maize (*Zea mays*) with whole white sorghum (*Sorghum bicolor*). Cooking and steeping times and dry matter losses decreased as the percentage of whole sorghum increased in the blend. Tortilla characteristics were best when 25% of yellow maize was replaced by whole sorghum. Tortillas were prepared from sorghum pearled to remove 5, 11, and 15% of the original kernel weight. Cooking time and dry matter losses during cooking decreased as the level of pearling increased. Color improved as the level of pearling increased. Good quality tortillas were obtained from sorghum pearled at 15%. Tortillas were also prepared by replacing 25, 50, 75, and 100% of yellow maize with sorghum pearled at 15%. Cooking and steeping times were decreased as the percentage of pearled sorghum in the blend increased. Tortillas from blends of yellow maize and pearled sorghum had a lighter color than 100% yellow maize tortillas. Tortillas made from 100% yellow maize, 75% yellow maize and 25% whole sorghum, and sorghum pearled at 15% were equally accepted by a 40-member test panel composed of 17 Latin Americans and 23 North Americans. Properly processed sorghum can be partially or totally substituted for yellow maize in tortilla production.

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Tortillas are a staple food for many people in Mexico and Central America (Herrera 1982, Futrell and Jones 1982). Traditionally, tortillas are made from maize; however, sorghum (*Sorghum bicolor* (L.) Moench) can be, and in some Central American countries is, used successfully at the village level as a complete or partial replacement for maize in tortilla production. Sorghum is grown to ensure a stable grain supply. By careful selection of sorghum variety and by partial decortication of the sorghum using dry milling procedures, good tortillas have been produced in the laboratory from white and red sorghum cultivars (Khan et al 1980, Iruegas et al 1981, Bedolla et al 1983). Most of the research on sorghum tortillas has involved cooking the sorghum and maize separately and blending the masas. This article summarizes a series of experiments designed to develop practical methods of cooking maize and sorghum mixtures. The relative chemical, physical, and organoleptic properties of the tortillas were compared.

MATERIALS AND METHODS

Sorghum and Maize Samples

A commercial food grade yellow maize (YM) hybrid (Asgrow 404Y) was grown near Uvalde, TX, in 1980. A commercial white sorghum (CS3541) with a thin pericarp and tan plant color was grown in 1980 at Halfway, TX, in the sorghum performance nursery. The samples were cleaned and stored at −4° C until used. The sorghum matured under dry conditions so the grain was not spotted or discolored.

Cooking Procedures

Three kilograms of YM, whole sorghum (WS), pearled sorghum, and mixtures of YM and whole or pearled sorghum were cooked with the amounts of water and alkali specified in Table I. In each case, preliminary tests were performed to subjectively determine optimum cooking and steeping times (Khan et al 1980). A steam cooker (Groen model TDC/2-20) was used for all studies. After cooking, the mixtures were allowed to steep for the times specified in Table I. Then the cooked, steeped grain (nixtamal) was washed with tap water, ground into masa with a stone grinder, shaped into tortillas, and cooked (Choto 1983, Khan et al 1982).

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Sorghum Pearling

The sorghum was pearled by using the abrasive decortication procedure of Reichert and Youngs (1976). The cleaned sorghum (5 kg) was fed into the mill and abraded for 95, 110, and 220 sec, which removed 5, 11, and 15%, respectively, of the initial dry weight of the kernel. The sorghum was not tempered or pretreated. The bran was removed by screening and aspiration.

Dry Matter Losses

Dry matter losses (DML) to the steep and wash water were determined by collecting and blending the steep and wash waters. Then, 10-ml aliquots were evaporated to dryness, in a forced air oven at 80° C for 6 hr. The residue was expressed as a percentage of the original dry weight of the grain.

Enzyme Susceptible Starch

Enzyme susceptible starch (ESS), an index of the extent of starch damage or gelatinization, was determined as described by Johnson

TABLE I
Cooking Procedures for Tortilla Preparation[a]

Sample: Yellow Maize (%)	Sample: Sorghum (%)	Water (L)	CaO (g)	Cooking (min): YM[b]	Cooking (min): WS[c]	Steeping (hr)
	Whole					
100	0	9	30	90	0	4
75	25	9	30	75	20	4
50	50	9	30	70	20	3
25	75	9	30	35	25	0.5
0	100	9	30	0	35	0.0
	15% Pearled					
100	0	9	30	90	0	4
75	25	9	30	90	2	4
50	50	9	30	70	3	3
25	75	9	30	50	4	0.5
0	100	4.5	6	0	8	0.0
Whole Sorghum		9	24	35		0.0
Pearled	5%	9	24	15		0.0
	11%	9	24	12		0.0
	15%	4.5	6	8		0.0

[a]The cooking procedure included washing except for 15% pearled sorghum.
[b]YM = yellow maize.
[c]WS = whole sorghum.

et al (1980). Before analysis, the samples were dried in a forced air oven at 30° C overnight and ground through a 1-mm screen using a Udy cyclone grinder.

Color Value

Tortilla color was measured with a Gardner color meter model XL10-CDM. Five tortillas per replicate were measured as follows: Each tortilla was cut in quarters and put in a glass dish used specifically for the color meter. The apparatus was standardized with a yellow tile ($L = 77.3$, $a = -1.7$, $b = 22.8$). Color index E, reported by Bedolla et al (1983), was computed using the formula:

$$E = (L^2 + a^2 + b^2)^{1/2}.$$

Organoleptic Evaluation

Tortillas made from 100% YM, 75% YM:25% WS, or pearled sorghum (15%) were randomly sampled by 40 untrained panelists (17 Latin Americans and 23 North Americans). A nine-point hedonic scale (Peryam and Girardot 1952) that classifies sensory factors (9 = like extremely to 1 = dislike extremely) was used by the panelists. The characteristics evaluated were color, flavor, texture, and overall acceptability. Every panelist was asked to evaluate each of the three products tested.

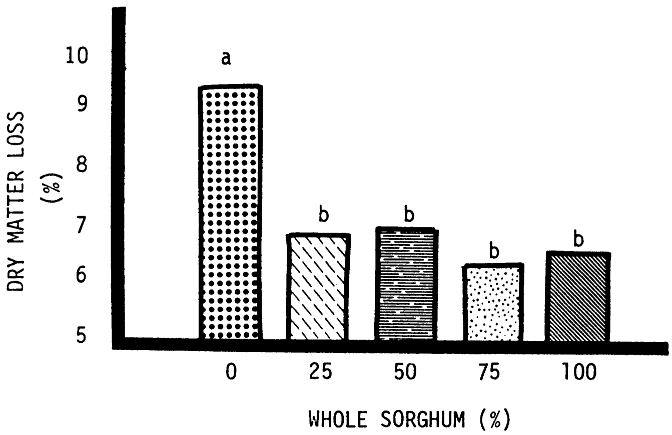

Fig. 1. Dry matter losses during processing of tortillas from yellow maize-whole sorghum blends. (Bars with the same letters are not significantly different at the $\alpha = 0.05$ level).

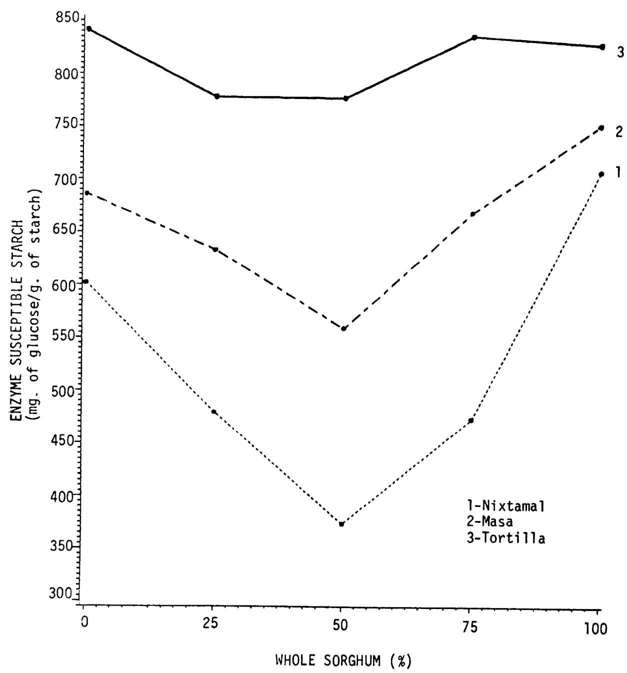

Fig. 2. Enzyme susceptible starch during the processing of tortillas from blends of yellow maize and whole sorghum, cv = 0.05 for the enzyme susceptible starch method.

Texture

Texture of tortillas was evaluated with the Instron (universal testing machine model 1122) using a Food Technology Corporation CS-1 Cell (Kramer type) as described by Bedolla et al 1983. Measurements were taken immediately after cooking the tortillas.

Experimental Design

The experiments were performed in a completely randomized design. Three observations for each property were measured on each of three days. Means were analyzed statistically by a one-way analysis of variance, and they were separated by Duncan's multiple range test (Snedecor and Cochran 1980).

RESULTS

Tortilla Preparation from YM-WS Blends

Tortillas were made from 75:25, 50:50, and 25:75% YM and WS and compared to 100% YM and 100% WS tortillas. During the processing, 100% YM tortillas had the highest DML (Fig. 1). Statistically, differences in DML were not significant for the YM-WS blends. The reductions in processing time provide sorghum with an advantage over 100% YM. Less energy is used, and material losses were significantly lower.

ESS values were higher for 100% WS than for 100% YM nixtamals (Fig. 2). However, nixtamals containing mixtures of both had greatly reduced ESS values, indicating lower gelatinization. Because each sample was given different cooking and steeping times to produce tortillas with optimum characteristics, the great variation in ESS values of the nixtamals was surprising. It suggests that the mechanical action of grinding can at least partially compensate for the overall reduction in starch gelatinization. In these trials, the masa of WS was slightly sticky. None of the YM-WS mixtures were sticky. All of them had good to excellent handling characteristics. The stickiness of WS disappeared when the masa was allowed to rest at room temperature for 30–60 min. In the YM-WS mixtures, the sorghum tends to be overcooked whereas the maize is undercooked. Then, during grinding, the overcooked sorghum endosperm forms a film that completely surrounds the undercooked particles of corn endosperm. The net effect is to produce masa with good handling properties. Then during baking of the tortillas, additional starch is gelatinized, which forms the infrastructure of the tortillas.

Substitution of WS for YM caused the tortilla to become darker with reduced red and yellow color values (Table II). Blends of 75:25 YM-WS were essentially similar in color to 100% YM tortillas. Therefore, the tortillas containing 75%YM:25%WS were selected for testing in a consumer taste panel. Texture of tortillas made from

TABLE II
Color and Texture of Tortillas Made from Mixtures of Yellow Maize and Whole Sorghum[a]

Yellow Maize (%)	Whole Sorghum (%)	Color[b] L	a	b	E[c]	Texture (N)[d]
100	0	60.4 a	+5.3 a	+27.0 a	66.0	449.0 b
75	25	56.0 b	+5.6 a	+24.0 b	61.2	443.0 b
50	50	56.5 b	+3.6 b	+21.0 c	60.4	443.0 b
25	75	51.5 c	+3.5 b	+19.0 c	55.0	396.0 c
0	100	52.1 c	+2.3 c	+16.0 d	55.6	502.0 a

[a] Data represent means of three replicates with five observations per replicate. Means within columns followed by the same letter are not significantly different at the 5% level.
[b] L = Lightness (100 = white, 0 = black); $+a$ = red, $-a$ = green; $+b$ = yellow, $-b$ = blue.
[c] Color index.
[d] N = Newtons.

100% YM, 75%YM:25%WS, and 50%YM:50%WS was not significantly different as measured by the Instron (Table II). Tortillas from 100% WS had the highest values. The lowest values for texture were for the 25%YM:75%WS tortillas. The softer texture of the 25%YM:75%WS was desirable, but the color of the tortillas was dark.

Tortillas from Whole and Pearled Sorghum

Tortillas were prepared using decorticated sorghums that had 5, 11, and 15% of the dry weight of the kernel removed. Optimum cooking procedures were subjectively determined for each treatment (Table I). The absence of steeping and washing and the short cooking time explain the lowest value of DML in the waters

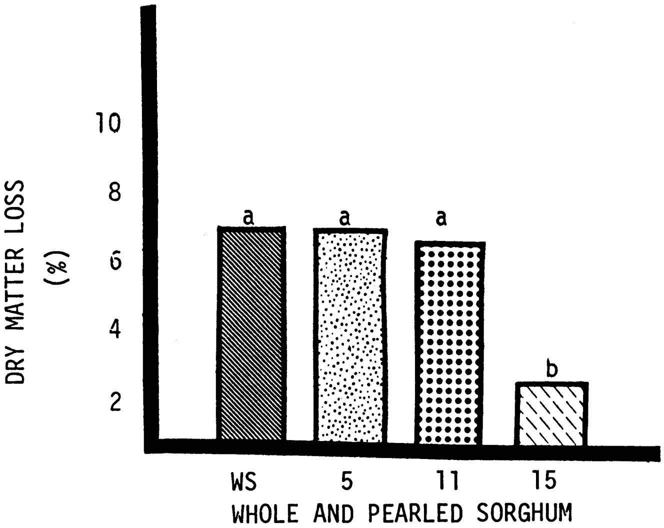

Fig. 3. Dry matter losses during the processing of tortillas from whole sorghum and pearled sorghum (5,11, and 15% of original dry weight removed). (Bars with the same letters are not significantly different at the $\alpha = 0.05$ level.)

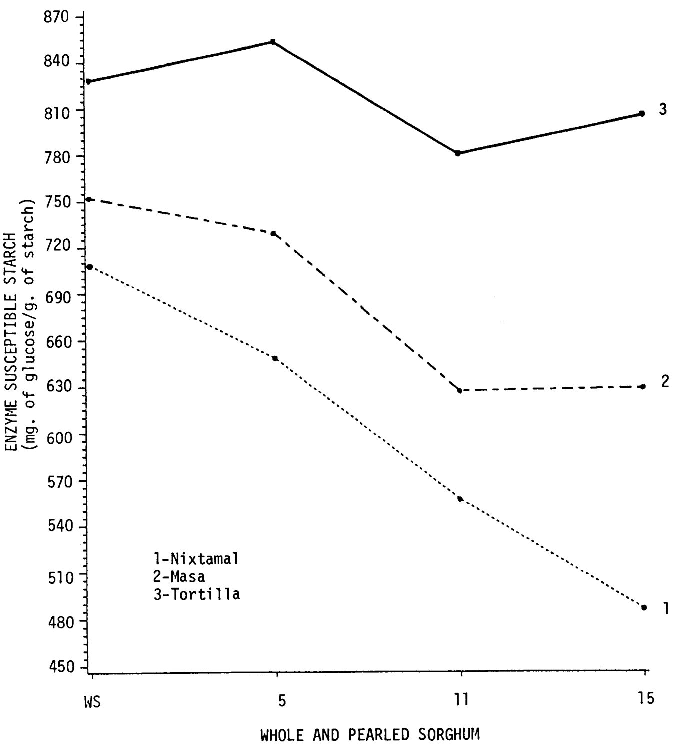

Fig. 4. Enzyme susceptible starch during the processing of tortillas from whole sorghum and pearled sorghum (5,11, and 15% of the original dry weight removed), cv = 0.05 for the enzyme susceptible starch method.

TABLE III
Color and Texture of Tortillas Made from Whole and Pearled Sorghum[a]

Sorghum	Color[b] *L*	*a*	*b*	Texture *E*[c]	(N)[d]
Whole	52.0 c	+2.5 a	+16.0 b	55.6	502.0 b
Pearled					
5%	53.0 c	+1.6 b	+16.7 b	55.6	404.0 b
11%	56.0 b	+1.0 b	+17.0 ab	58.5	477.0 b
15%	66.0 a	+1.0 b	+18.0 a	68.4	711.0 a

[a] Data represent means of three replicates with five observations per replicate. Means within columns followed by same letters are not significantly different at the 5% level.
[b] *L* = Lightness (100 = white, 0 = black); +*a* = red, −*a* = green; +*b* = yellow, −*b* = blue.
[c] Color index.
[d] N = Newtons.

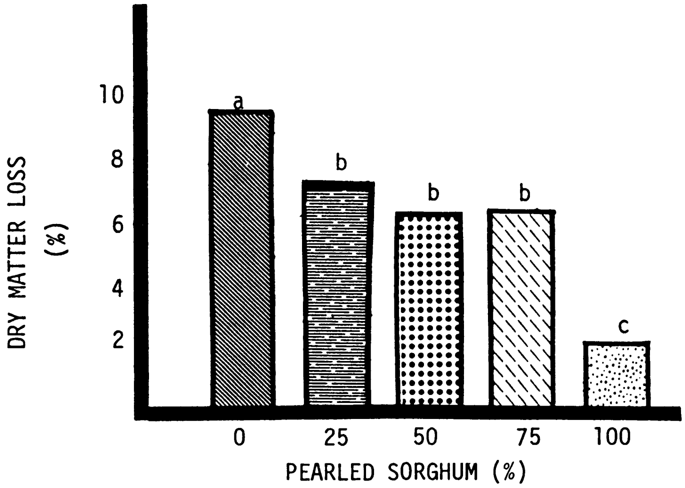

Fig. 5. Dry matter losses during the processing of tortillas from blends of yellow maize and pearled sorghum (15% of the original weight removed). (Bars with the same letters are not significantly different at the $\alpha = 0.05$ level.)

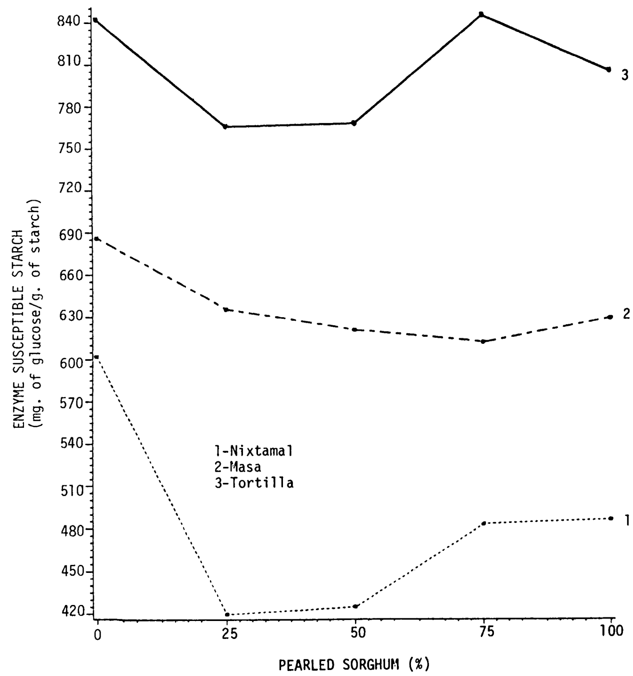

Fig. 6. Enzyme susceptible starch during the processing of tortillas from blends of yellow maize and pearled sorghum (15% of the original weight removed), cv = 0.05 for the enzyme susceptible starch method.

for sorghum pearled to 15% compared to WS and 5 and 11% pearled sorghum (Fig. 3). The ESS value (Fig. 4) for the nixtamal decreased as the pearling level increased. This is related to cooking time, because as the extent of pearling increased, less cooking time was required. Starch granules were further disrupted or gelatinized during the grinding process. It was important to optimize the cooking time of 15% pearled sorghum to avoid or minimize the problem of stickiness at the masa stage. Bedolla et al (1983) reported stickiness of masas made from sorghums with levels of pearling higher than 11%. In this study, we cooked the 15% pearled with low alkali concentration, limited amounts of water, and shorter cooking time, as suggested by Bedolla et al (1983). The masa produced had acceptable handling properties. The cooking time was critical. A small increase in cooking time did cause sticky masa during the preliminary trials. As the level of pearling increased, tortilla color became lighter (Table III). Tortillas prepared from pearled sorghum (15%) were comparable in color (E = 68.4) to tortillas made fom 100% white maize (E = 69.0) as reported by Bedolla et al (1983). The texture (Table III) of tortillas made from pearled sorghums (5 and 11%) was similar to that of tortillas made from WS. However, the texture from 15% pearled sorghum tortillas was much firmer.

YM-Pearled Sorghum (15%) Tortillas

Cooking and steeping times (Table I) decreased as the percentage of pearled sorghum (15%) increased to 50% or more in the mixture. The DML decreased for the YM:pearled sorghum mixtures (Fig. 5). Differences in ESS (Fig. 6) values existed at the nixtamal stage and reflected differences in cooking and steeping times. The ESS values increased when the nixtamal was processed into masa and again when the masa was baked into tortillas. Stickiness problems were not observed when the mixtures were cooked as presented in Table I.

Color (Table IV) was highly affected by the proportion of sorghum in the mixture. Yellow color (b values) decreased as the percentage of pearled sorghum in the blend increased. Tortillas made from pearled sorghum (15%) also were the lightest. The texture of tortillas containing maize and pearled sorghum mixtures (Table IV) was softer than those from 100% YM or 100% pearled sorghum.

TABLE IV
Color and Texture of Tortillas Made from Blends of Yellow Maize and Sorghum Pearled to Remove 15% of the Original Weight[a]

Yellow Maize (%)	Sorghum 15% Pearled (%)	Color[b] L	a	b	Texture E^c	(N)[d]
100	0	60.0 b	+5.0 ab	+27.0 a	66.0	449.0 b
75	25	59.0 b	+5.7 a	+26.0 a	64.7	258.0 c
50	50	58.5 b	+4.0 b	+23.0 b	63.0	212.0 c
25	75	56.0 c	+4.0 b	+21.7 b	60.2	254.0 c
0	100	66.0 a	+1.0 c	+18.0 c	68.4	712.0 a

[a] Data represent means of three replicates with five observations per replicate. Means within columns followed by the same letters are not significantly different at the 5% level.
[b] L = Lightness (100 = white, 0 = black); $+a$ = red, $-a$ = green; $+b$ = yellow, $-b$ = blue.
[c] Color index.
[d] N = Newtons.

TABLE V
Organoleptic Evaluation of Tortillas by a Panel of Latin Americans and North Americans[a]

Rating	100% YM[b]	Pearled Sorghum (15%)	75%YM:25%WS[c]
Color			
Latin	6.9 a	7.5 a	6.5 a
USA	7.6 a	6.7 a	7.1 b
Texture			
Latin	7.2 a	7.2 a	6.6 a
USA	7.1 a	5.7 b	7.3 a
Flavor			
Latin	7.5 a	6.7 a	6.4 a
USA	6.9 a	5.9 a	6.7 a

[a] Data represent means of the rankings given by the 17 Latin Americans and 23 North Americans. Means within lines with the same letters are not significantly different at the 5% level.
[b] YM = Yellow maize.
[c] WS = Whole sorghum.

Acceptability of Tortillas by a Taste Panel

The organoleptic panel results are presented in Table V. Acceptability scores for color were not statistically different at the 0.05 level of significance (Table V). Latin Americans showed a slightly higher preference for the color of pearled sorghum (15%) tortillas (Table V). This was expected since most of them consume tortillas made from white maize. North American panelists, on the other hand, tended to prefer the color of 100% YM tortillas. North American panelists were most familiar with tortillas or tortilla products made from YM or from blends of yellow and white maize and may have associated yellow color with a good color tortilla.

Instron values for the 15% pearled sorghum tortillas indicated an extremely tough texture (Table IV). In spite of the tough texture, Latin Americans' acceptance of the texture of 15% pearled sorghum tortillas was greater than acceptance by the North Americans. We cannot explain this discrepancy. However, texture measurements obtained with the Instron cannot exactly resemble human evaluations that also include mouthfeel, visual appearance, and other factors.

Flavor scores for 100% YM tortillas were the highest from both Latin Americans and North Americans. On the other hand, tortillas made from 15% pearled sorghum were categorized as slightly acceptable by North American panelists and moderately acceptable by Latin Americans. The shortened cooking time and reduced amount of lime used in preparing tortillas from 15% pearled sorghum may have been responsible for the lack of flavor noted by panelists. However, when both groups (Latin Americans and North Americans) were asked to determine overall acceptability of the three products, 34% accepted 100% YM, 34% preferred 75%YM:25%WS, and 32% preferred 15% pearled sorghum. Thus, all were equal in terms of overall acceptability.

DISCUSSION

Mixtures of maize and WS or maize and pearled sorghums can be cooked and processed into acceptable tortillas. The exact cooking conditions will vary depending on specific local procedures and the ratio of maize to sorghum. Substitution of WS for maize could decrease the cooking and steeping times significantly. Use of pearled sorghums would reduce cooking time even more and could produce superior tortillas by removing undesirable color precursors in the sorghum pericarp. The bran obtained through pearling could be used for livestock feed.

In our opinion, the sorghum tortillas produced in these experiments were considerably more acceptable than most of the commercial tortillas currently available in the Mexico City, Mexico, area. Whole or pearled sorghum mixed with YM available in Mexico would produce tortillas with improved color. For example, Bedolla (*personal communication*) conducted trials in commercial tortilla factories in Mexico and, using traditional equipment, produced sorghum tortillas with good taste, color, and acceptability.

The sorghum used in this study had excellent characteristics for tortilla production. Sorghum hybrids with white kernels, tan plant color, and high yield potential are being developed by plant breeders. Environment affects sorghum quality as well (Khan et al 1980). Thus, one of the best strategies for use of sorghum in tortillas is to grow accepted, food quality hybrids that mature grain under dry conditions and to decorticate the sorghum to remove the color precursors. This combination will allow sorghum to be used effectively. Economic, social, and psychological factors limit sorghum acceptability, but it is technologically feasible to use sorghum to produce acceptable tortillas.

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